

ELASTOMERIC AIR-PURIFYING RESPIRATOR USE BY HEALTHCARE WORKERS: PHYSIOLOGICAL IMPACT

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Abstract

Aims: This study examined the physiological impact of wearing one model of a half-facepiece elastomeric air-purifying respirator on healthcare workers and associated changes in respirator microenvironment (dead space) oxygen and carbon dioxide levels.

Methods: Ten healthcare workers exercised at two different work rates, with and without a half-facepiece elastomeric air-purifying respirator, while physiological variables (heart rate, respiratory rate, tidal volume, minute volume, oxygen saturation, transcutaneous carbon dioxide) and respirator dead space gas measurements were monitored.

Results: Significant decreases in the breathing rate (p<0.05) at both work rates and an increase in the tidal volume at the lower work rate (p<0.01) were noted when wearing the respirator, as well as mild-to-moderate increases in transcutaneous carbon dioxide levels. Subjective ratings of comfort and exertion indicated that the respirator was well tolerated. Respirator deadspace mixed inhalation/exhalation oxygen and carbon dioxide levels did not meet Occupational Health and Safety Administration ambient workplace standards (these standards apply to the workplace, not respirators).

Conclusion: The use of a half-facepiece elastomeric air-purifying respirator by healthcare workers does not impose a significant physiological burden upon the wearer over a one hour period at work rates common to the healthcare environment and is well tolerated, but retention of carbon dioxide is a concern that will require further study.

Introduction

- Recent outbreaks of respiratory infectious diseases (e.g., SARS, pandemic H1N1, avian influenza) have amplified concerns over the availability of filtering facepiece respirators (e.g., N95 FFR, etc.) for healthcare workers (HCWs).
- During a 42-day pandemic, the Institute of Medicine estimated that 90 million FFR might be needed. Manufacturers of FFR might not be able to keep up with demand because of limited surge capacity, disruption in overseas inputs, and stockpiling by some nations.
- Half-facepiece elastomeric air-purifying respirators (EAPR) have been suggested as one solution because they offer potential advantages of improved face seal (for some wearers), easier donning and doffing, enhanced user seal check capability, the ability of the facepiece to be decontaminated multiple times, the capacity for use by single or multiple HCWs, and potential cost savings.
- Widespread use of EAPR in the healthcare industry has not occurred, and little is known about their physiological impact on HCWs.
- This study, part of a larger investigation of multiple types of respiratory protection equipment that was carried out over five months, was undertaken to assess the physiological burden imposed upon HCWs when wearing EAPR continuously over one hour at work rates common to HCWs.

Methods

- Ten healthy HCWs (no prior experience with EAPR) were recruited.
- A LifeShirt® sensor vest (Fig. 1) equipped with respiratory impedance plethysmography (RIP) bands was utilized for monitoring heart rate (HR), respiratory rate (f_B), and tidal volume (V_T). The minute volume (V_E) was derived from the product of $f_B \times V_T$.
- Mixed inhalation/exhalation respirator dead space ($V_{D \text{ resp}}$) O_2 and CO_2 were monitored via a sampling port at 18 samples/sec.
- Transcutaneous CO_2 (tcPCO₂) and oxygen saturation (SaO₂) were monitored continuously by the Tosca 500 sensor (Fig. 2) attached to the left earlobe.
- Subjects were treadmill-exercised without respirators (controls) and with one model of an EAPR (Fig. 3) at rates identified as comparable to stationary work (1.7 mph) and nursing patient care duties (2.5 mph) for a period of 1 hour (typical duration for nurses).
- Visual Analog Scales were used to query subjects on comfort and exertion every 5 minutes.
- Subjects filled out questionnaires at the end of each exercise session regarding any issues subjectively associated with discomfort while wearing EAPR.
- EAPR were weighed before and after each exercise session to determine H₂O retention.

Results

Table 1. Physiological responses during use of an EAPR at a 1.7 mph (2.74 km/h) and 2.5 mph (4.03 k/hr) work rates over a one hour period.

Variables 1.7 mph	1 min	15 min	30 min	45 min	60min
$V_{D \text{ resp}} O_2$ (%)	17.74 (±0.55)	17.9 9 (±0.51)	17.67 (±0.54)	17.84 (±0.26)	17.90 (±0.37)
$V_{D \text{ resp}} CO_2$ (%)	2.47 (±0.50)	2.47 (±0.42)	2.65 (±0.52)	2.49 (±0.33)	2.49 (±0.35)
SaO ₂ (%)	98.56 (±0.71)	98.59 (±0.77)	98.49 (±0.66)	98.47 (±0.67)	98.47 (±0.57)
tcPCO ₂ (mm Hg)	40.83 (±3.87)	44.56 (±5.24)	44.71 (±5.15)	44.84 (±5.78)	44.95 (±5.96)
f_B	21.71 (±5.36)	22.83 (±5.09)	22.33 (±4.43)	23.61 (±4.12)	23.42 (±3.13)
V_T (mL)	904 (±227)	927 (±217)	920 (±275)	882 (±264)	901 (±198)
V_E (L)	18.75 (±5.34)	20.67 (±4.70)	19.95 (±5.34)	20.32 (±5.32)	21.08 (±5.52)
HR	92.60 (±6.27)	95.58 (±8.04)	96.47 (±8.82)	95.55 (±9.15)	96.82 (±8.67)
Variables 2.5 mph	1 min	15 min	30 min	45 min	60 min
$V_{D \text{ resp}} O_2$ (%)	17.46 (0.68)	17.87 (0.46)	17.95 (0.82)	17.85 (0.79)	17.89 (0.60)
$V_{D \text{ resp}} CO_2$ (%)	2.47 (0.45)	2.47 (0.44)	2.47 (0.34)	2.49 (0.40)	2.43 (0.36)
SaO ₂ (%)	98.43 (0.96)	98.53 (0.87)	98.53 (0.80)	98.38 (0.91)	98.33 (0.49)
tcPCO ₂ (mm Hg)	40.31 (4.17)	43.98 (7.01)	43.40 (6.80)	43.41 (7.70)	43.89 (8.20)
f_B	23.35 (±5.48)	23.46 (±5.88)	23.84 (±5.26)	23.14 (±4.68)	23.90 (±4.14)
V_T (mL)	925 (±231)	988 (±244)	958 (±244)	921 (±223)	941 (±218)
V_E (L)	21.08 (±6.16)	21.09 (±6.88)	22.72 (±7.54)	22.69 (±6.21)	21.10 (±5.21)
HR	96.82 (±8.67)	95.07 (±10.35)	100.02 (±8.77)	101.07 (±9.01)	101.06 (±9.14)



Figure 1. LifeShirt®



Figure 2. Tosca transcutaneous CO₂ sensor and pulse oximeter.



Figure 3. North 5500-30L respirator

Results

- All 10 subjects completed all phases of the study.
- Significant decreases in the f_B were noted for the EAPR at both work rates (p<0.05).
- An increase in V_T was noted at the lower work rate (p<0.01).
- EAPR use resulted in non-significant increases in the mean tcPCO₂ at the lower work rate (3.2 mm Hg)(p=0.09) and higher work rate (2.1 mm) (p=0.27),but half the subjects experienced elevated tcPCO₂ levels (range, 45.4 – 62.8 mm Hg).
- There were no significant differences in the $V_{D \text{ resp}} CO_2$ concentrations at either work rate (2.50% vs. 2.47%) (p=0.61).
- There were no significant differences in $V_{D \text{ resp}} O_2$ concentrations at either work rate (17.85% vs. 17.81%) (p=0.80).
- EAPR moisture retention averaged 1.32 gm/hr at the lower work rate and 1.62 gm/hr at the higher work rate (p=0.72).
- There were no significant differences between controls and EAPR in exertion scores at the low work rate (0.60 vs. 0.83) (p=0.67) and higher work rate (1.05 vs. 1.07) (p=0.96).
- There were no significant differences between controls and EAPR in comfort scores at the low work rate (1.10 vs. 1.17) and higher work rate (1.40 vs. 1.31) (p=0.67 for both comparisons).
- Subjective complaints related to respirator features, in descending order of frequency, included: facial heat, skin irritation, EAPR weight, facial sweating, facial pressure, respirator slippage, EAPR odor, and speech difficulty.

Conclusions

- The use of EAPR by HCWs over one hour at work rates compatible with the healthcare environment does not impose a significant physical burden on the wearer.
- Variable increases in tcPCO₂ among half the subjects imply that CO₂ retention occurs and requires further study.
- $V_{D \text{ resp}} O_2$ and CO₂ levels do not meet OSHA ambient workplace standards (these standards apply to the workplace, not respirators)
- Subjective ratings of comfort and exertion suggest that EAPR are well tolerated by HCWs.

Outputs

Roberge RJ, Coca A, Williams JW, Powell JB, Palmiero AJ. (2010) Reusable elastomeric air-purifying respirators: physiological impact on healthcare workers. American Journal of Infection Control (in press).

Stakeholders

Respirator users Healthcare workers
Respirator manufacturers Respiratory protection program managers

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